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Methods for Estimating Size at Maturity of Male *Homarus americanus*

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Abstract

There are no convenient field techniques for the determination of maturity in male lobsters, and attempts to develop one have been complicated by the existence of two states of maturity: physiological (presence of spermatozoa in the vasa deferentia) and functional (capable of successful mating). Changes in relative cheliped size appear to be associated with functional maturity, and this is the state of greatest interest to assessment biologists. Inflections in rate of crusher cheliped growth can be demonstrated on a weight:weight basis, but this is inconvenient for field use. Conventional allometric growth analysis for changes in cheliped volume will also reveal points of inflection, but these are only valid for the stock or sub-stock represented by the sample being analyzed, and the method cannot be used for maturity determination with individuals. In this paper a male maturity index - the Crusher Propodite Index, or CPI - is described which is convenient for field use, is applicable to all male lobsters irrespective of stock, and can be used to estimate maturity of individual lobsters as well.

Résumé

Il n'existe pas de méthodes convenables de détermination, sur le terrain, de la maturité de homards mâles. La présence de deux états de maturité, physiologique (présence de spermatozoides dans les vasa deferentia) et fonctionnelle (aptitude à s'accoupler avec succès), complique cette détermination. Les changements de taille relative des chélipèdes semblent être associés avec la maturité fonctionnelle, et c'est là la condition qui présente le plus d'intérêt pour le biologiste qui fait l'évaluation. On peut démontrer les points d'inflexion dans le taux de croissance de la pince broyeuse sur une base de poids: poids, mais cette méthode présente des inconvénients sur le terrain. Une analyse conventionnelle de la croissance allométrique dans le but de détecter des changements de volume des chélipèdes montre également les points d'inflexion, mais ceux-ci ne sont valides que pour le stock ou le sous-stock représenté par l'échantillon analysé, et l'on ne peut utiliser cette méthode pour déterminer la maturité d'individus. Nous décrivons ici un indice de maturité des mâles - l'indice du propodos de la pince broyeuse, ou CPI (Crusher Propodite Index) - pouvant être convenablement utilisé sur le terrain, et qui est applicable à tous les homards mâles, quel que soit le stock, et pouvant enfin servir à estimer la maturité de homards individuels.

Introduction

In female lobsters, oviposition is conclusive evidence of sexual maturity, and the development of such secondary sexual characteristics as increased abdomen width or engorged abdominal glands can be correlated with oviposition and used to estimate maturity in non-ovigerous females (Aiken and Waddy 1980a, b; Ennis 1980; Waddy and Aiken 1980a, b). In males, physiological maturity occurs when spermatozoa can be detected in the vasa deferentia, but such males cannot be considered functionally mature until they are capable of mating with and inseminating a female. Physiological maturity apparently occurs at a much smaller size than functional maturity (Aiken and Waddy 1980a, b; Briggs 1976; Briggs and Mushacke 1979, 1980; Krouse 1973; Templeman 1935, 1944; Van Engel 1980), but functional maturity is the more important consideration for the management biologist. Unfortunately, there are no convenient field techniques for estimating size at functional maturity of male American lobsters.

The only conclusive evidence for functional maturity in male lobsters is mating competence, an event that is too infrequently observed to be of any value. Relative carapace length and relative cheliped length, weight and volume are known to undergo changes that are positively associated with maturation in male lobsters (Aiken and Waddy 1980a, b; Ennis 1971, 1980; Templeman 1939, 1944), but it has been difficult to establish the relationship between development of these secondary sexual characteristics and the ability of the male to copulate with and inseminate a female. Ennis (1980) pointed out that since success in agonistic sexual encounters is related to cheliped size, the sudden increase in relative cheliped size is most likely an indication of onset of functional maturity. Although there is no direct evidence to support this, it seems like a reasonable assumption, since we do know that physiological maturity occurs well before the increase in relative cheliped size. However, Ennis (1980) used the ratio of crusher cheliped weight to animal weight to demonstrate this change, and this is not a method that is easily used in the field. The principles of allometric growth have been used to estimate maturity in other decapods (eg., Somerton 1980b; Watson 1970). In this report we will apply allometric growth analysis to male Homarus americanus from the southern Gulf of St. Lawrence and the Bay of Fundy, and describe a male maturity index that can be easily used in field assessments and is much more versatile than methods previously described.

Methods

Male and female lobsters were caught by commercial lobster trap in four different areas: Seal Cove and the vicinity of North Head on Grand Manan in the Bay of Fundy (94 males between 25 July and 6 October, 1978); near North Rustico on the Gulf side of Prince Edward Island (715 males during May and June of 1979 and 1980); and near Miminegash, on the Northumberland Strait side of Prince Edward Island (227 males during August and September of 1979 and 1980). In addition, the chelipeds of 260 females ranging from 58 to 230 mm CL were measured. An estimate of crusher propodite volume (CPV) was obtained from measurements of the length, width and thickness (height) of the crusher propodite. All measurements were to 0.01 cm with a vernier caliper. Maximum length of the propodite is measured from the rear of the articular condyle to the most anterior point on the propodite. Width is measured across the "palm" from the top of the ridge beneath the articulation with the dactyl to the outer margin of the propodite, perpendicular to the long axis. Thickness, or depth, is measured at the midpoint of the propodite "palm" (see Fig. 1). Of these three, the measurement of width is subject to the greatest error due to variations in angle of measurement and shape of propodite, but this error has a relatively minor impact on the final value.

Results and Discussion

Years ago, Templeman (1935) recognized that cheliped size is a male secondary sexual characteristic comparable to abdomen width in females, and attempted to demonstrate an inflection between mature and immature phases by plotting cheliped propodite length against total length. This technique was never widely used, and the inflection Templeman described became even more difficult to demonstrate with measurements based on carapace length rather than total length. Squires (1970) noted a relationship between crusher claw weight and male maturity, and his observations were extended by Ennis (1971, 1980) who correlated CL and crusher cheliped weight and demonstrated an inflection that he assumed was related to functional maturity. Determination of crusher claw and whole animal weight would be inconvenient in the field because weights can be difficult to obtain on board small fishing and research vessels, and the technique necessitates removal of a commercially valuable part of the lobster.

We obtain an estimate of crusher propodite volume (CPV) from the product of length, width and thickness. Cheliped propodite volume increases as a power of carapace length according according to the allometric growth equation $Y = aX^b$ (see Hartnoll 1978). The level of allometric growth of cheliped volume and carapace length is similar for females of all sizes from all areas, and is best described by an equation of the form $Y = 0.22\ X^{2.98}$. The correlation coefficient for the 260 females measured in this study was 0.98.

In contrast, the values for the empirical constants a and b are different for males from each geographical area, and presumably this is a reflection of differences in size at onset of maturity. These differences are apparent from the power curves in Fig. 1, which indicate that males from Miminegash (Northumberland Strait) mature at a slightly smaller size than those from North Rustico (Gulf of St. Lawrence), and that Gulf of St. Lawrence males mature at a smaller size than those from the Bay of Fundy. These relationships parallel what is known about the effect of temperature on size at maturity (Aiken and Waddy 1980a, b).

The distribution of plotted points around these regression lines is also interesting. In Fig. 2, actual values are plotted for females and North Rustico males. Note that the points for North Rustico males larger than 9 cm CL (i.e., mature) fall uniformly *above* the regression line, and give the impression of a linear rather than a power relationship.

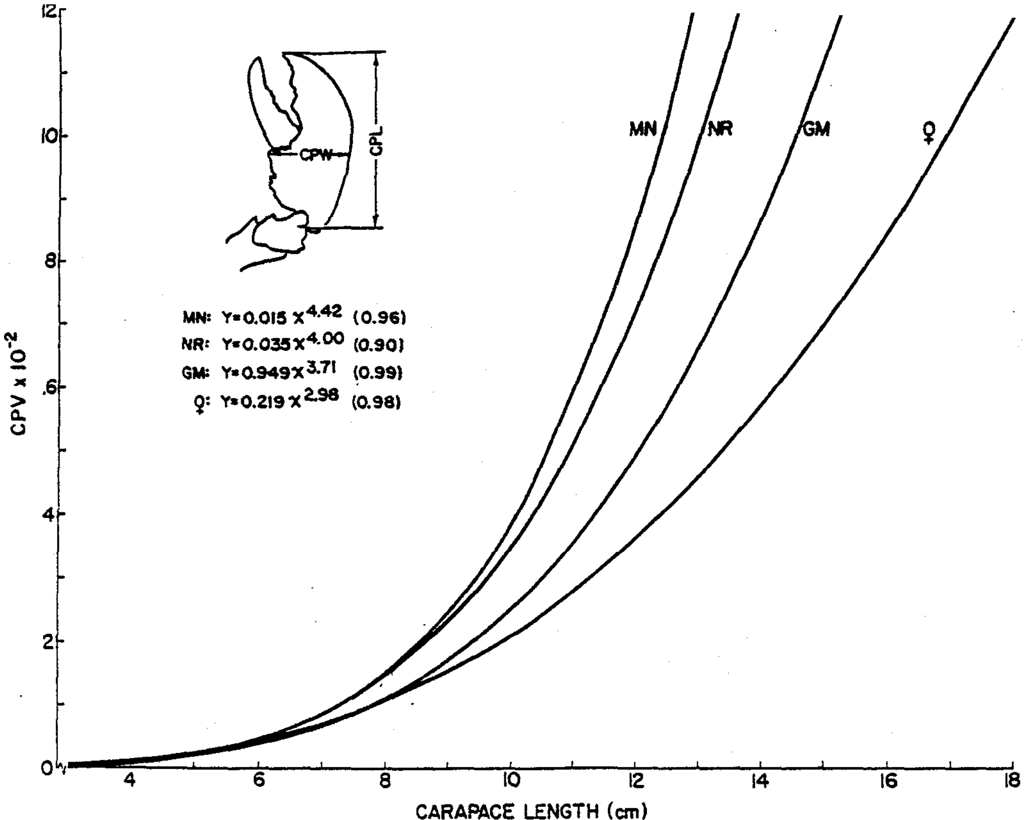


Figure 1. Power curves for males from Miminegash (MN), North Rustico (NR), and Grand Manan (GM) compared with the female "baseline." Correlation coefficients (r) are given in brackets after each equation.

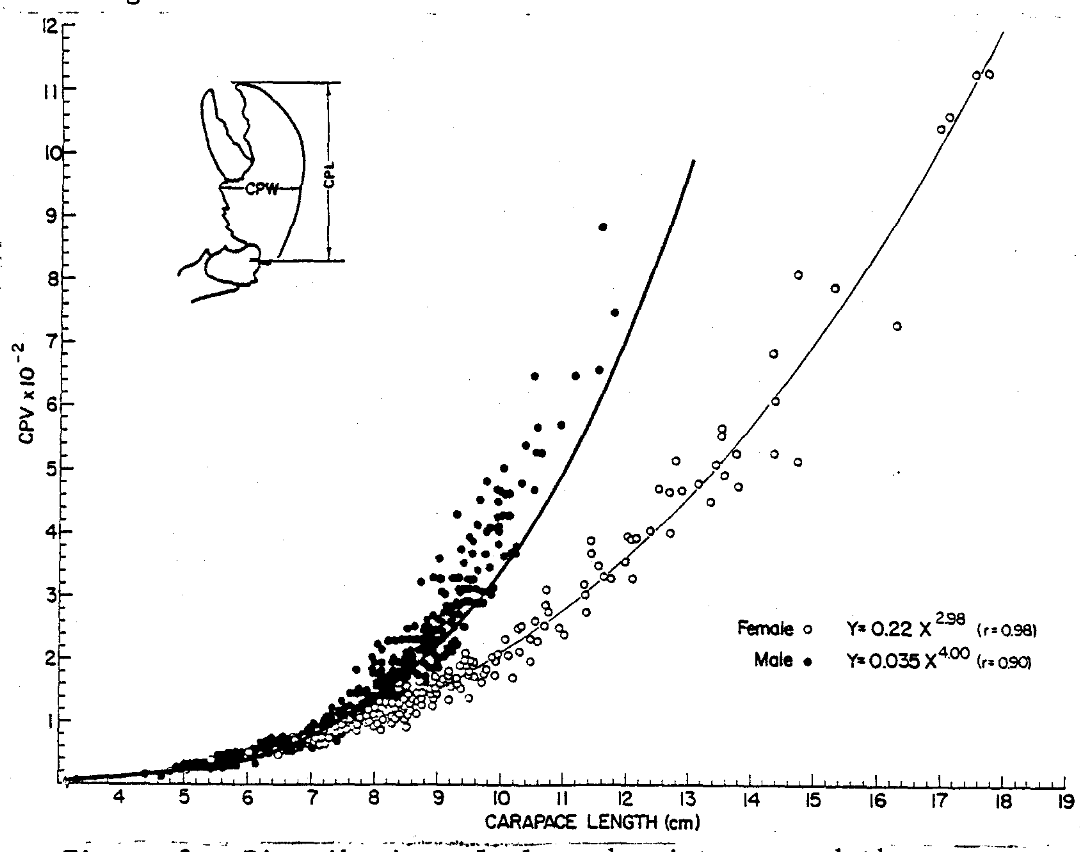
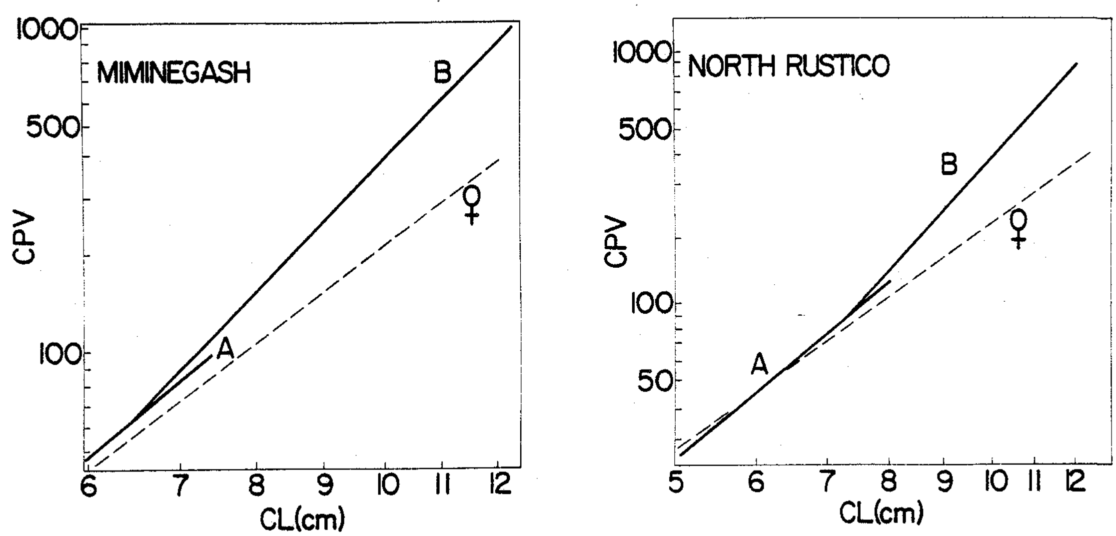


Figure 2. Distribution of plotted points around the power curve for females from several areas and males from North Rustico. Note that the male regression line diverges from the female line around 7 cm CL, and the plotted points for mature males fall above the regression line.

In their discussions of relative growth, both Hartnoll (1978) and Somerton (1980b) emphasize the superiority of logarithmic transformation for the display of sexual maturity data. The crusher propodite volume (CPV) data for males from Miminegash, North Rustico and Grand Manan are displayed this way in Fig. 3, along with the female baseline for comparison. The North Rustico data (largest sample) and the Grand Manan data (greatest range of carapace lengths on either side of maturity) are the most reliable. Inflections between immature and mature levels of allometry were identified by examination of plotted points. Least squares regression analysis was then applied to data lying to either side of this inflection point, and intersects were calculated. Somerton (1980a, b) has developed a computer program which can be used to increase the precision of fit, but his technique was not available for this analysis.



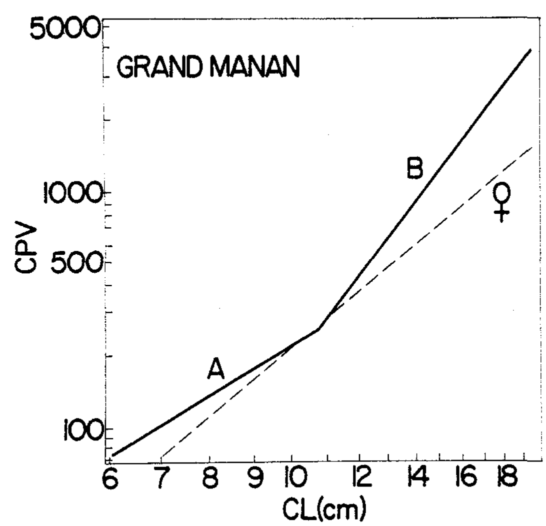


Figure 3. Allometric growth of crusher propodite volume (CPV) and carapace length (CL). Immature (A) and mature (B) phases are initially separated by visual inspection of plotted points. Female CPV data are plotted for reference. Equations and calculated intersects are given in Table 1.

With log transformation of CPV and CL, the calculated intersects occur at 6.67, 7.29 and 10.77 cm CL for Miminegash, North Rustico and Grand Manan, respectively, and corroborate the relationships suggested by the power curves in Fig. 1. Intersects were also calculated on the female baseline on the assumption that the female regression line might be a more realistic approximation of the level of allometry for the male immature phase (which is unavoidably biased by inclusion of a certain number of mature and maturing animals near the point of intersect). These intersects occur at 6.10, 6.88 and 10.94 cm CL. Regression equations, correlation coefficients and intercepts for this figure are summarized in Table 1.

Table 1. Equations and calculated intersects for correlations of crusher propodite volume (CPV) and carapace length (CL) in Fig. 3. Intersects in italics are on the female regression line.

				Calculated intersects		
Location		b a	r	CL	CPI	CPV
MIMINEGASH	A:	Log Y = 3.3953 Log X − 0.9508	(0.84)	6.67	24	70
	B:	Log Y = 4.2665 Log X − 1.6686	(0.92)	*6.10*	*18*	*40*
NORTH RUSTICO	A:	Log Y = 3.3994 Log X − 0.9817	(0.94)	7.29	23	88
	B:	Log Y = 4.6374 Log X − 2.0463	(0.91)	*6.88*	*21*	*69*
GRAND MANAN	A:	Log Y = 2.1956 Log X + 0.1412	(0.96)	10.77	21	256
	B:	Log Y = 4.5817 Log X − 2.3219	(0.96)	*10.94*	*21*	*274*
ALL AREAS (Females)		Log Y = 2.981 Log X − 0.659	(0.98)			

Log transformation analysis does show a change in the level of allometric growth in all three samples examined, and therefore yields a mathematical estimate of the size at which the influence of maturity is expressed in these local stocks. It does not, however, tell us anything about the state of maturity of any individual in those samples. Furthermore, the criteria developed are valid only for lobsters from the specific geographical area from which they are derived. Information from lobsters obtained from Northumberland Strait cannot be applied to lobsters only a few miles away on the Gulf side of Prince Edward Island, let alone to lobsters in the Bay of Fundy.

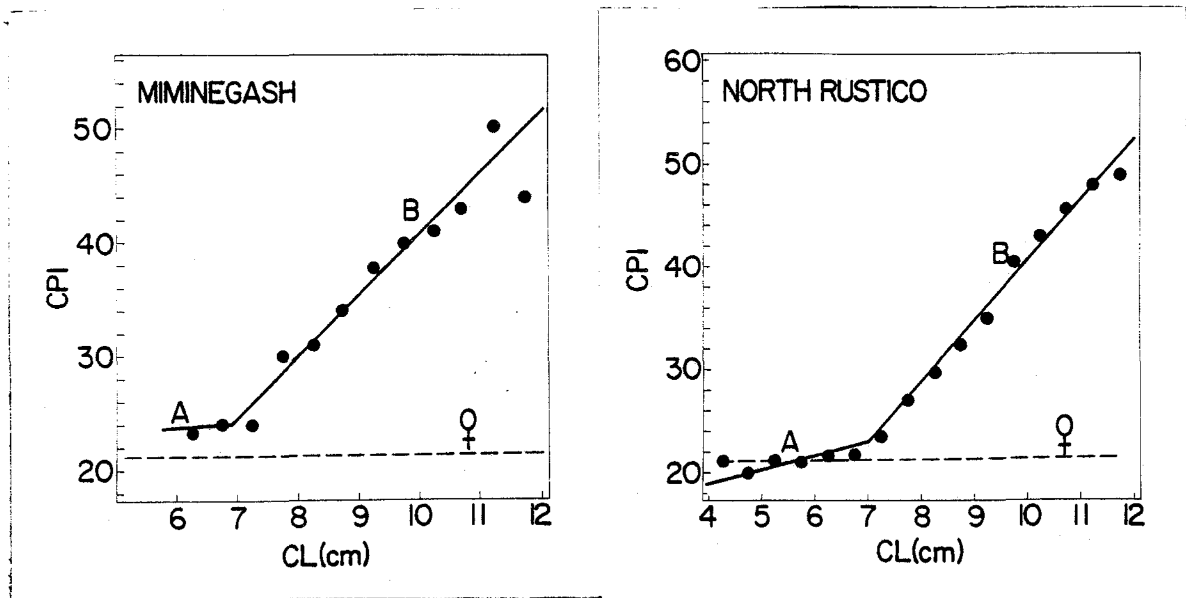
More flexibility can be obtained if, instead of plotting log transformed data, a maturity index is developed from the CPV data. In the terminology we have evolved, a *Maturity Index* is a derived value that bears a constant relationship to maturity, irrespective of the size or geographical origin of the lobsters under study. The *Abdomen Width Index*, or AWI, is an example of a female maturity index (Waddy and Aiken 1980a).

The value of the constant b is approximately 3.0 for the power curve of CPV on CL for females, so CPV/CL^3 produces a horizontal line when plotted against carapace length. When CPV is multiplied by 100 for convenience, the value for the constant a is approximately 21-22. Since comparable values are also obtained with immature males, irrespective of size, $100(CPV)/CL^3$ may be considered a male maturity index, and termed the *Crusher Propodite Index*, or CPI. CPI values much larger than 22 are indicative of a higher level of allometric growth and therefore of a positive influence of maturity on CPV.

In earlier discussions of this concept (Aiken and Waddy 1980a, b), we followed the principle established with the female maturity index and divided CPV by CL. This was referred to as the "Anderson Cheliped Index" and identified by the symbol CPV. When subsequent data revealed that the crusher cheliped of immature males developed at the same rate as that of females, and that the value for the constant b was 3.00 for females, irrespective of size, it was obvious that CL^3 should be used to develop a male maturity index, not CL. Therefore, the Anderson Cheliped Index has been discarded, CPV is now used as the symbol for crusher propodite volume (the product of crusher propodite length, width and thickness), and the male maturity index is identified as a Crusher Propodite Index, or CPI.

The relationships between CPI and CL for males from Miminegash, North Rustico and Grand Manan are shown in Fig. 4. Plotted points on these graphs are means of data within 5 mm CL groups. Inflections are initially identified by eye and then linear regression analysis is applied to actual data for the immature (A) and mature (B) phases (for equations, see Table 2). Calculated intersects are 6.92, 7.03 and 11.33 cm CL for Miminegash, North Rustico and Grand Manan, respectively, or slightly larger than those calculated with log transformed CPV data (Fig. 3). The female baseline is included for reference. The Miminegash sample contains very few lobsters smaller than 63 mm CL, and the disparity between the female baseline and the immature phase in this sample of males indicates a bias, which probably means the intersect should be at a slightly smaller CL than calculated. This is not the case for North Rustico or Grand Manan, where the immature male points fall along the female baseline. It is important that the CPI value at point of inflection is 24 or less whether the male in question is 70 mm CL from the southern Gulf, or 120 mm CL from the Bay of Fundy.

Bearing in mind the caveat that the precise relationship between cheliped volume and functional maturity has not been established in lobsters, but recognizing that changes in cheliped allometry are routinely used in maturity assessments, we suggest that CPI is more versatile than logarithmic transformation because it is applicable to all male lobsters, irrespective of origin or stock, and can be used to estimate maturity of individual lobsters as well.



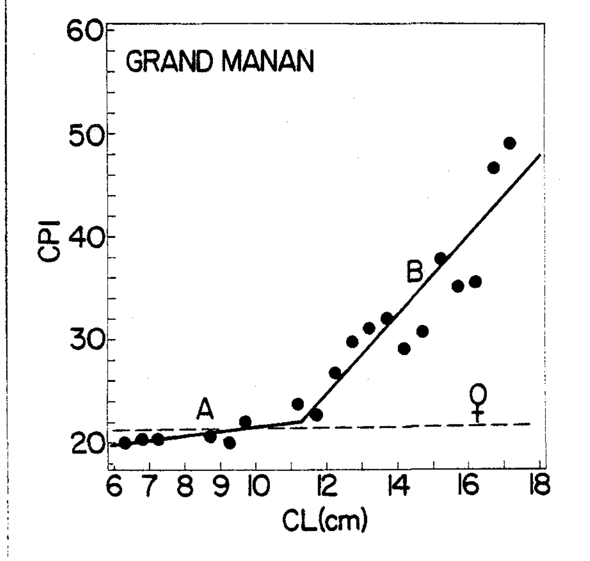


Figure 4. Crusher propodite index (CPI) plotted against carapace length (CL) to indicate change in level of allometry associated with maturity. Plotted points are means of 5 mm CL groups. Equations were calculated from actual data. Immature (A) and mature (B) phases were initially separated by eye. Regression lines were calculated by least-squares regression. Equations and calculated intersects are given in Table 2.

Table 2. Equations and calculated intersects for correlations of crusher propodite index (CPI) and carapace length (CL) in Fig. 4. Intersects in italics are on the female regression line.

Location		b	a	r	Intersects CL	CPI	CPV
MIMINEGASH	A:	Y = 0.33 X	+ 21.87	(0.61)			
					6.92	24	80
	B:	Y = 5.39 X	- 13.15	(0.71)			
					6.39	*21*	*56*
NORTH RUSTICO	A:	Y = 1.32 X	+ 13.58	(0.36)			
					7.03	23	81
	B:	Y = 5.93 X	- 18.81	(0.69)			
					6.77	*23*	*81*
GRAND MANAN	A:	Y = 0.49 X	+ 16.89	(0.28)			
					11.33	22	326
	B:	Y = 3.77 X	- 20.28	(0.73)			
					11.07	*22*	*291*
ALL AREAS (Females)		Y = 0.03 X	+ 21.12				

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